The Expansion of Russian Arctic Fossil Fuel Extraction and Distribution in a Warming World

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Introduction

Globally, climate change presents major implications for the development of fossils fuels. Climate change is especially relevant in the Arctic, where surface air temperatures warm at approximately twice the global rate (Anisimov et al., 2007). The Arctic is also one of the world's most significant regions of untapped oil and gas; in Russia, the region comprises over 35,700 billion cubic meters of natural gas (Figures 1 & 3) and over 2,300 million metric tons of oil and condensate (Figures 2 & 4) (Stephenson & Agnew, 2015; Ministry of Natural Resources, 2018). Both globally and in Russia's Arctic, fossil fuel development depends upon a complex entanglement of local firms, extraction sites and distribution systems (Figures 5 & 6). In particular, Russia's distribution network, and the state's control over it, plays a key role in linking local production to global consumption (Stephenson & Agnew, 2015). Russia relies on over 10,000 kilometers of pipeline as well as the emerging Northern Sea Route (NSR) to bring Arctic hydrocarbons to market, East and West (Figure 6) (Stephenson & Agnew, 2015). However, environmental factors such as climate, sea ice, permafrost and geographic remoteness, as well as infrastructure capabilities and global market demand emerge as key constraints to fossil fuel development at local, national and global scales (Figure 6) (Stephenson & Agnew, 2015). Yet despite challenges, Arctic reserves will remain important in Russia, as the petroleum and gas industries comprise 60% of the country's exports and 30% of its GDP (Depersio, 2018; Stephenson & Agnew, 2015). With important implications for the global environment and international markets, the world needs to understand the current state of Russian Arctic oil and gas extraction and distribution, especially given scientifically recognized global environmental change. Thus, this poster maps out Russia's Arctic fossil fuel landscape, with particular attention to oil and gas potential, distribution and environmental change.

Methods

Identifying Major Explored Arctic Oil and Gas Sites: McGee used the Ministry of Natural Resources 2016-17 "State Report on the Composition and Use of Raw Materials of the Russian Federation," to identify the Russian Arctic's significant oil and natural gas reserves and extraction sites. The report also included data on total reserves and 2016-17 extraction levels for each site.

Mapping Major Arctic Oil and Gas Sites: Our primary method for collecting geospatial data involved internet searches of Russian fossil fuel databases. For example, McGee used information from an online catalog of information on Russian oil and gas fields, as well as project information listed on "Gazprom" and "Novatek" company sites, to identify general spatial coordinates for each oil and gas field (Neftyaniki, 2019; Газпром, 2019; Новатэк, 2019). In some cases, external news articles, videos and maps were cross referenced in order to validate findings. McGee then utilized Google Earth to remotely confirm specific oil and gas fields and infrastructure and to improve location precision. In order to determine specific coordinates for each site, McGee located major infrastructure comprising each field site and chose the largest, most central structure to represent the field coordinates.

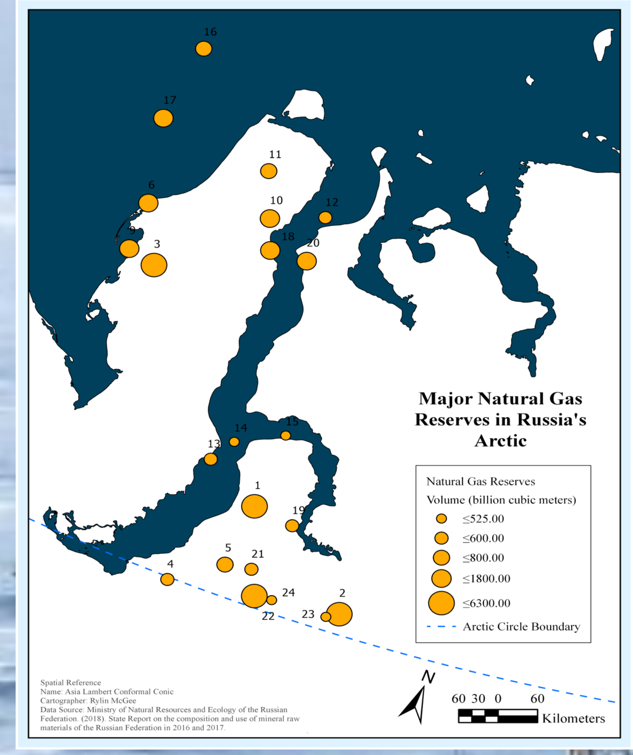
Identifying and Mapping Hydrocarbon Distribution: Frequently, Russian news articles and company project sites revealed the method of oil and gas distribution for each field. Such insight was then confirmed by analyzing Google Earth imagery. A majority of fields depend upon a dense network of pipelines throughout Russia, the majority of which connect to Europe. Due to the large number of pipelines present in Southern and Western Russia, we only show Gazprom's major Arctic pipeline projects. After collecting various pipeline maps and imagery found on Gazprom's website, McGee georeferenced and digitized the pipelines (Газпром, 2019). Other fields rely on the Northern Sea Route to ship hydrocarbons to markets; these fields and their associated ports were identified in a similar manner by analyzing project information included on Russian company websites, in the Russian media and in a presentation by Russian state owned company Rosatom (Ruksha, 2019). Once the fields and their respective ports were identified, McGee utilized geospatial data provided by the World Port Index to map major Russian ports in the Arctic, as well as Google Earth Imagery for ports not included in the index (National Geospatial Intelligence Agency, 2019.)

Mapping Sea Ice and Permafrost Extent: Sea ice extent data was downloaded directly from the National Snow & Ice Data Center (Fetterer et al., 2017). Permafrost extent data was downloaded directly from the Russian Academy of Science's "Land Resources of Russia" dataset, and is intended to provide a general understanding of permafrost cover from a broad perspective (Stolbovoi & McCallum, 2002).

Environmental Challenges

According to the Arctic Climate Impact Assessment (ACIA) program, the area of permafrost, or ground that is permanently frozen for two consecutive years, in the northern hemisphere will decrease 10 to 18% by 2030; 15 to 25% by 2050; and 25 to 50% by 2080 as a result of climate change (Pavlenko & Glukhareva, 2010). This means that normally frozen regions will begin to thaw and recede, increasing the risk that accidents will occur involving pipelines and hydrocarbon infrastructure built in permafrost regions. As shown in Figure 5, many pipelines in Russia's Arctic are built on full and partial permafrost zones, and are susceptible to changing soil dynamics, and thus damage and accidents, with extremely high repair costs.

Maps and Figures



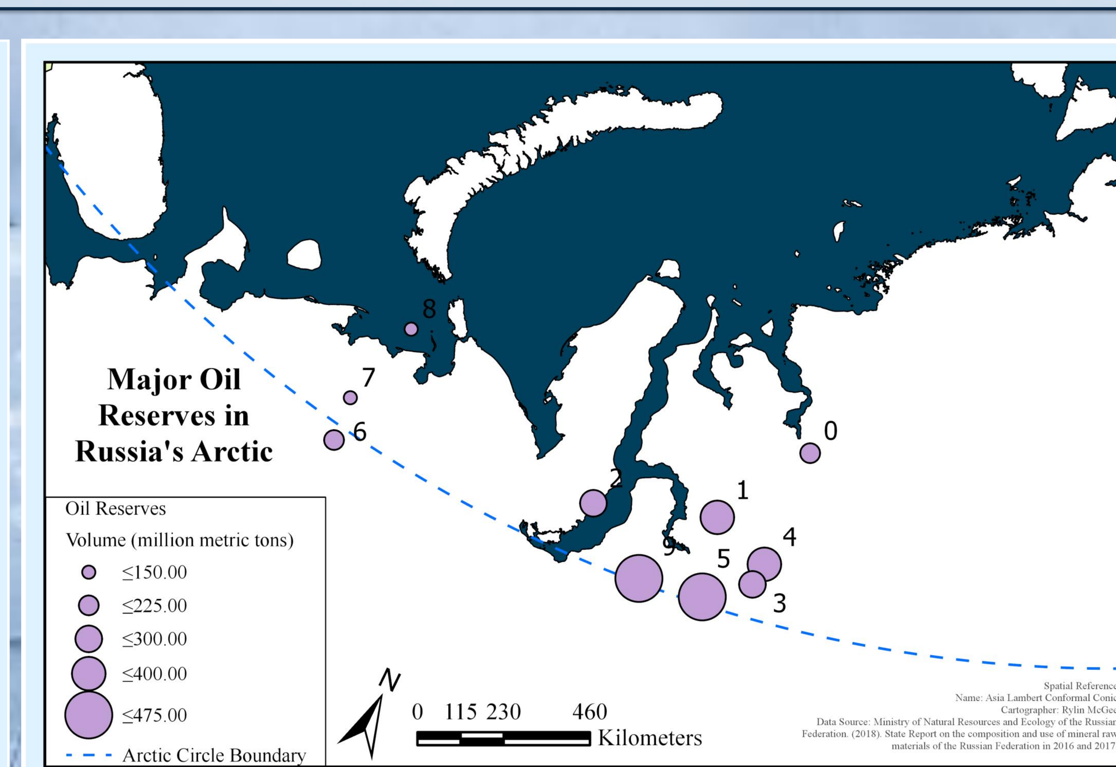


Figure 1 (left): Major natural gas fields as identified by the Russian Ministry of Natural Resources (2018) are mapped on the Yamal and Gydan Peninsulas, the epicenters of Russia's Arctic hydrocarbon development. The peninsulas can be located in Russia by the red box in Figure 6. The relative volume of each field's recoverable natural gas reserves are reflected by the map's symbology, and specific values can be identified using Figure 3.
Figure 2 (right): Major oil fields as identified by the Russian Ministry of Natural Resources (2018) are mapped throughout the West Siberian Arctic. The relative volume of each field's recoverable oil reserves are reflected by the map's symbology. Specific values can be identified using Figure 4.

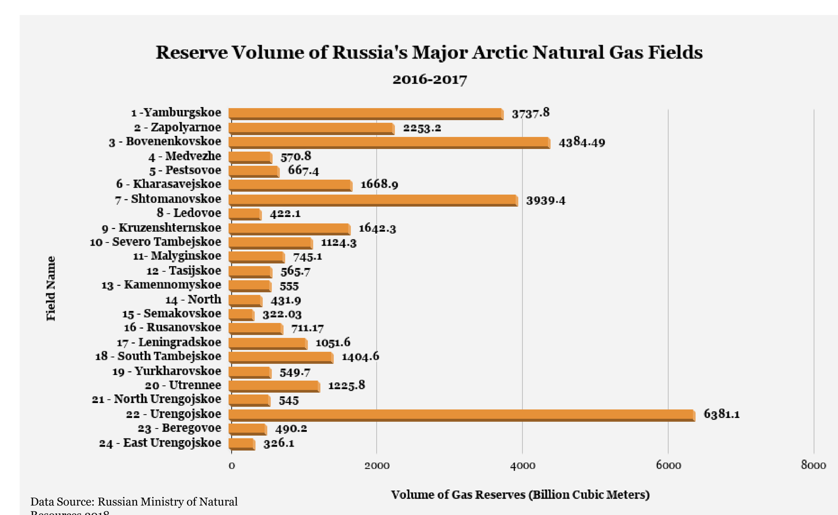


Figure 3: Graph corresponding to the Figure 1, Map of Major Natural Gas Reserves in Russia's Arctic, detailing major natural gas fields and the total volume of recoverable reserves in each field.

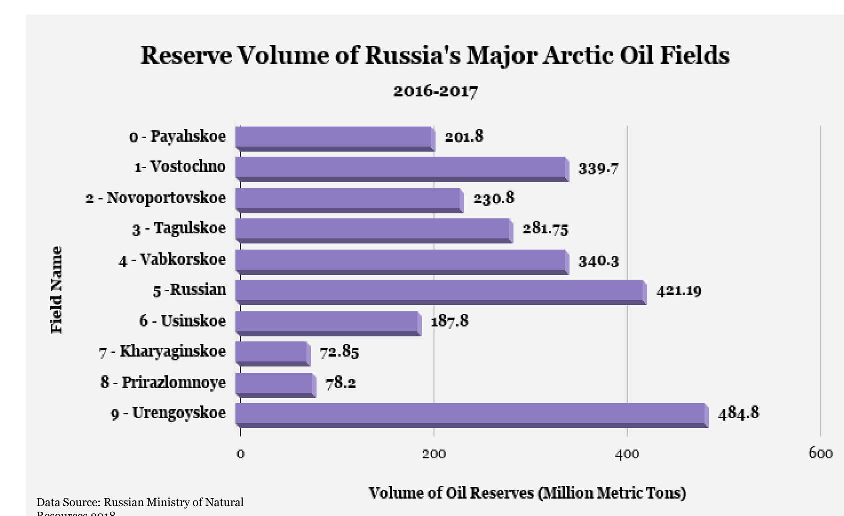


Figure 4: Graph corresponding to the Figure 2, Map of Major Oil Reserves in Russia's Arctic, detailing major oil fields and the total volume of recoverable reserves in each field.

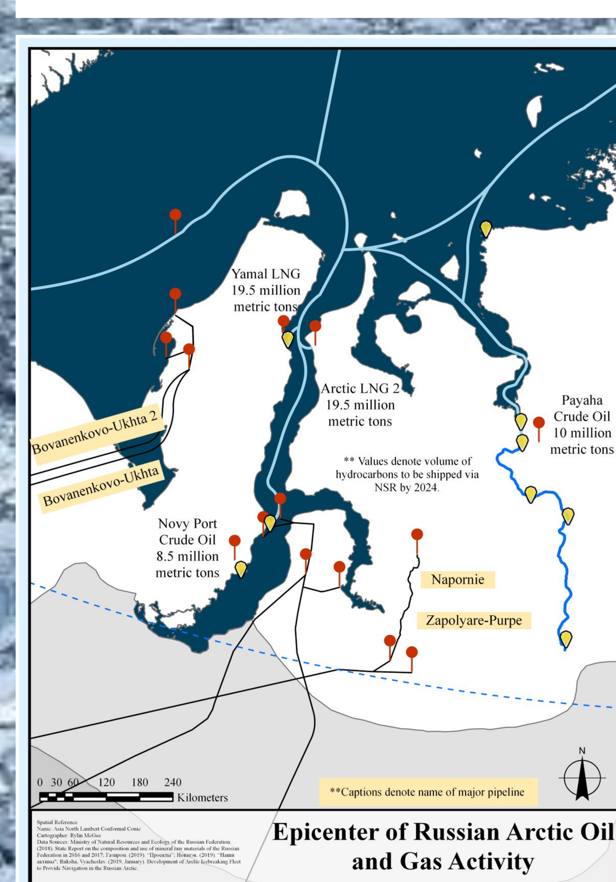


Figure 5: Distribution network on the Yamal and Gydan Peninsulas. Major pipelines transporting hydrocarbons to Europe as well as the Northern Sea Route are highlighted, along with the major ports and oil and gas fields connected to them. Fields and projects projected to supply the NSR by 2024 are also shown (Ruksha, 2019).

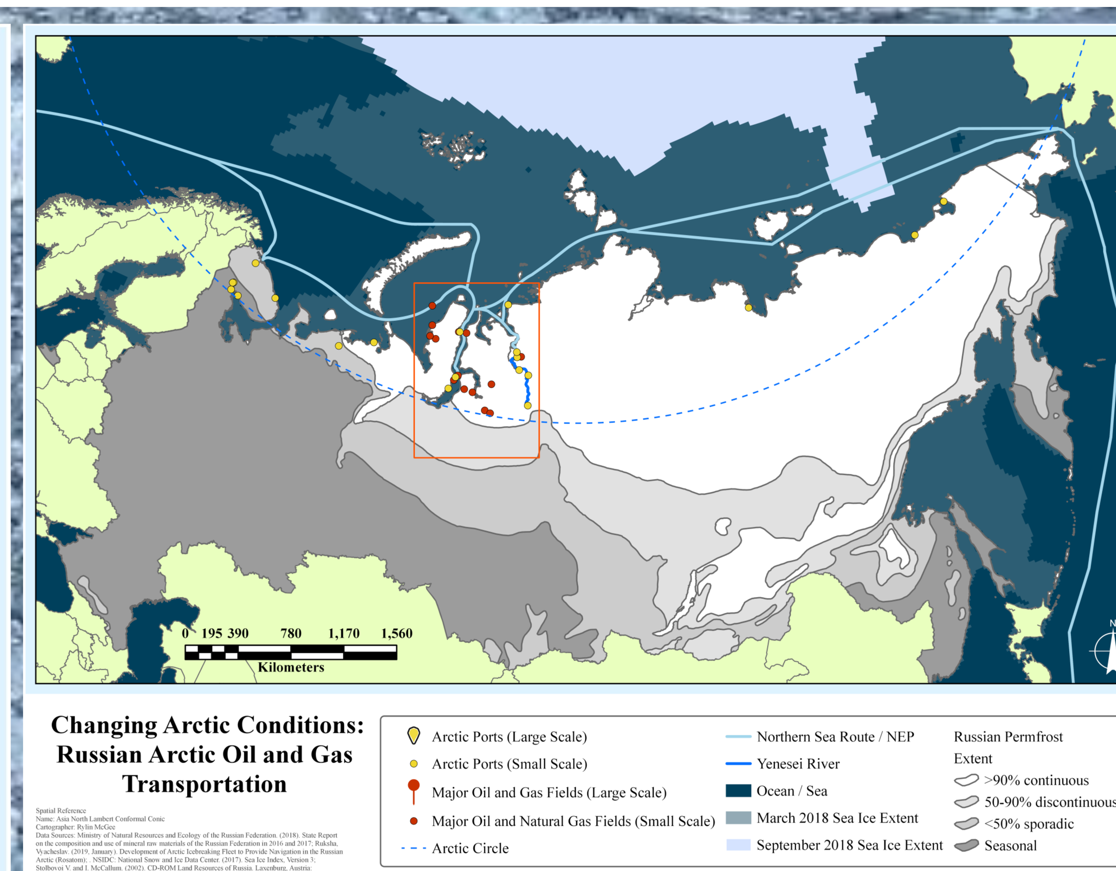


Figure 6: Russia's 2002 permafrost extent as well as 2018 summer and winter (September and March) sea ice extent are mapped alongside Russia's larger Northern Sea Route network. Changing environmental conditions present both challenges and opportunities for Arctic hydrocarbon transport, as thawing permafrost threatens the stability of existing fossil fuel infrastructure, whereas increasing sea ice melt further opens the NSR for hydrocarbon shipment.

Environmental Challenges Continued

Further, thawing permafrost poses a challenge ecologically, as sensitive Arctic environments become exposed to organic, chemical and radioactive wastes which once remained frozen in the ground. Because infrastructure designed for the disposal of waste and pollution also risks damage, important hydrological resources also become at risk (Pavlenko & Glukhareva, 2010). Beyond changing permafrost dynamics, increased sea level rise and coastal erosion pose threats to ports, tanker terminals and other infrastructure crucial to the transportation of oil and gas via the Northern Sea Route, and coastal settlements in particular are vulnerable to damage or even relocation. Further, as shown in Figures 1 & 2, Russia has several offshore oil and gas fields. Here, rising sea levels place greater barometric pressure on underwater pipelines, presenting the possibility of damage or even rupture, which would devastate the sensitive Arctic marine environment (Pavlenko & Glukhareva, 2010).

Transportation Opportunities

Despite environmental risks, Russia intends to continue exploiting its Arctic hydrocarbon resources through the development of its fossil fuel distribution scheme (Ministry of Natural Resources, 2018; Ruksha, 2019). According to Stephenson & Agnew (2015), ownership of transportation infrastructure within the hydrocarbon industry is nearly as important as ownership of the resources themselves, as transport connectivity allows states to quickly direct resources to high-demand markets. Thus, by connecting major Arctic oil and gas fields (Figure 5) to its extensive 10,000 kilometer pipeline network, a majority of which carries hydrocarbons to European markets, Russia is expanding its control of the resources and supplying the necessary infrastructure to bring recoverable reserves (Figures 3 & 4) to global markets. Further, Russia is taking major steps to further develop the Northern Sea Route, a decision which goes hand in hand with recent and projected decline in sea ice levels (Ruksha, 2019). By developing ports, investing in fossil fuel tankers and nuclear icebreakers, and constructing new oil and gas terminals, Russia is preparing to deliver recoverable Arctic fossil fuel resources to markets in both the East and West via the NSR, as shown by Figure 6 (Ruksha, 2019; Stephenson & Agnew, 2015). Notably, the NSR will allow Russia to supply markets in Pacific-Asia, which previously were served by only two oil pipelines (the "East Siberia-Pacific Ocean" and "Power of Siberia") and one LNG Plant (Sakhalin-2) (Stephenson & Agnew, 2015). Rosatom projects that by 2024, over 80 million tons of cargo and natural resources will be transported via the NSR annually, including 57.5 million tons of oil and liquefied natural gas (Ruksha, 2019). Figure 5 maps the Yamal LNG project (South Tambejskoe natural gas field), Arctic LNG 2 project (Utrennee natural gas Field), Novy Port Oil Field, and Payaha Oil Field, identified by Rosatom as the primary source of fossil fuel resources supplying NSR shipments (Ruksha, 2019). Further, projections show that by 2035, Rosatom will develop 9 new icebreakers in order to provide year round transportation on the NSR, shipping 70 million metric tons of fossil fuels annually to Asian-Pacific markets (Rushka, 2019). Thus, by expanding fossil fuel transport capacity through the development of Arctic pipelines and the NSR, Russia is creating new opportunities to continue sustaining current European hydrocarbon supply, as well as supply new markets in Pacific-Asia.

Conclusion

According to the International Panel on Climate Change, human influence on the climate is the dominant cause of observed warming since the mid-twentieth century (Allen et al., 2018). As a result of anthropogenic climate change, the world is experiencing profound alterations to human and natural systems, such as droughts, floods, sea level rise, increasingly severe weather events, among other ramifications. The Arctic is one of several ecosystems identified as being most at risk for severe climate change impacts (Allen et al., 2018). Despite environmental changes caused by global warming and the challenges they pose to hydrocarbon development, Arctic fossil fuels will likely be on the forefront of Russia's economic development in years to come. With over 35,700 billion cubic meters of recoverable natural gas and 2,300 million metric tons of recoverable oil and condensate, it is important to consider the future ramifications that the consumption of such fossil fuels will have on the climate, Arctic ecosystems and the world. But, Russia shows no intent to transition away from fossil fuel development in the near future. Thus, as the Arctic's physical environment continues to change in response to warming temperatures, it will become increasingly important to understand how the network of fossil fuel extraction and distribution activity in Russia's Arctic continues to develop and evolve in response. More research is needed on the complex multi-scalar relationships between climate change and fossil fuel extraction and distribution in the Russian Arctic.

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